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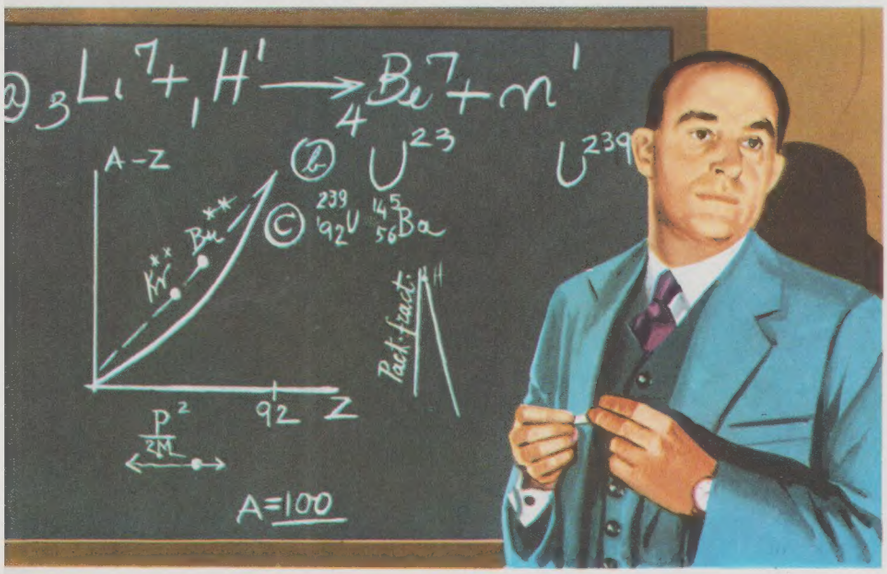
This issue contains the contents for Volume 15.

MATHEMATICS (part two)



Enrico Fermi used mathematics in his work on nuclear theory

SINCE the 1830s the advance of mathematics has been greatly helped by the discovery of *group theory*, a term first propounded by the French mathematician Evariste Galois (1811–1832) at the age of 20, on the night before he was killed in a duel. Group theory is a complicated application of mathematics and logic that rests on this principle: there are certain mathematical expressions which fall into groups, and if certain rules are applied to these groups they will yield answers of the same group.

Many other European mathematicians in the last century helped to develop group theory. In 130 years it has been a great aid in reunifying mathematics, bringing together sections of geometry and algebra long since deemed disconnected, distinct, unrelated, and independent. Enrico Fermi (1901–1954) and Paul Dirac (1902–) incorporated the theory in their development of nuclear theory; other physicists have used group theory to aid research in the basic structures of natural scientific phenomena. Physics today has thus been transformed almost wholly into a branch of mathematics, based on applications of electromagnetic, nuclear, atomic, and wave theory.

Group theory is one example of the type of logic that is being used in mathematics today. Logic is the science of accurate thinking. For instance, if everyone in the world is born of woman then you *deduce* logically that you are born of woman too; or, if we know that all angles of a triangle add up to 180°, and we know a certain figure to be a triangle, we deduce that the angles of this particular triangle add up to 180°. This process of reasoning from a general to a particular instance is called *deduction*.

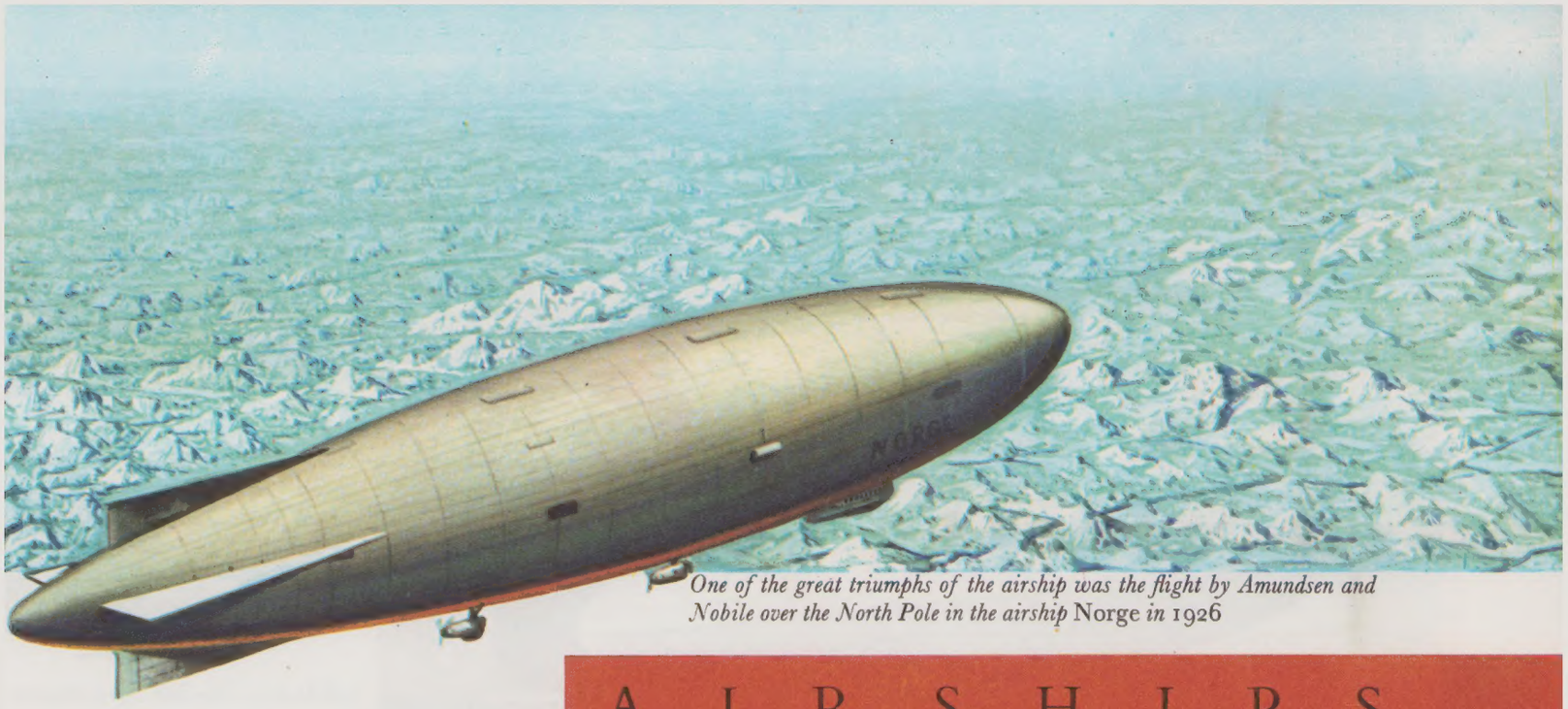
Another logical method used is called *induction*. If one sees many postmen in different places wearing uniforms, one might induce that all postmen wore uniforms. You might be right, but it does not follow logically, for one of the postmen might have lost or stained his uniform. However, it is quite logical to suppose that there is no reason why you should not be right. Indeed, in other instances of generalising from the particular you would be right. An example of induction is found in the work of Pierre Fermat (1601–1665), the French mathematician. He stated in his famous theorem that there exist no integral values of x, y, and z, such that $x^n + y^n = z^n$, where n is an integer greater than 2. This theorem has been proved true for certain values of n, namely, 3, 4, 5, 7, and some others, but there is no general proof for all values of n greater than 2. Fermat may be right – but his only proof is by induction.

Today there are signs that there may be a revolution in the teaching of mathematics. For instance, it is often pointed out in class that figures like 3, 8, and 11 are not numbers. In fact, no one has ever seen a number, which is an abstract idea of quantity. These figures are, in fact, only symbols for numbers. They are called numerals, and a numeral can mean almost anything you want it to mean. It depends on what *base* (number system) you are dealing with. This leads us to the question of computer mathematics.

MATHEMATICAL SYMBOLS

$=$	is equal to	$\int$	integral sign: used in calculus	π	3·14159....
$<$	less than; e.g. $2<4$	x^2	the 2 shows that x is squared	∞	infinity
$>$	greater than; e.g. $3>1$	$\neq$	is not equal to	$\propto$	is proportional to
$\leqslant$	less than or equal to	$\therefore$	therefore	$\pm$	plus or minus
$\geqslant$	greater than or equal to	$\because$	because	$\approx$	approximately equal to
$\in$	is a member of; e.g. 3∈prime numbers	log	logarithm	$\bar{x}$	the mean (average) value of x
		cos	cosine	i	$\sqrt{(-1)}$
$\sqrt{}$	square root; e.g. $2=\sqrt{4}$	sin	sine	( )	
$\equiv$	is identically equal to	tan	tangent	[ ]	brackets
Σ	the sum of such things as	e	2·71828....	{ }	

Previous page: Cards on which data has been punched will be fed into a computer (bottom); an abacus, an earlier calculating machine; and a ferrite ring, the basis of the computer's brain.



One of the great triumphs of the airship was the flight by Amundsen and Nobile over the North Pole in the airship Norge *in* 1926

AIRSHIPS

YOU are unlikely to see an airship in the sky today. Overtaken by the speed of the airliner, outclassed by the manœuvrability of the helicopter, these former giants of the air have passed into aeronautical history. In one respect, however, the airships were never surpassed. Their ability to lift was greater than that of the largest airliner, and because of this a few airships may still prove useful. Today new airships are being designed in Russia, but they will never carry passengers. Their task will be to transport large and unwieldy items of industrial and agricultural machinery over the vast distances of the Soviet Union and thus use the airship's greatest asset – its ability to lift and carry.

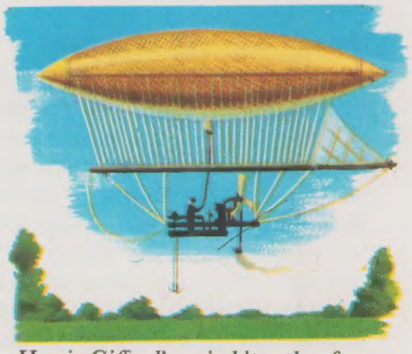
LIGHTER THAN AIR

Everyday experience gives the impression that the air surrounding us is weightless. In fact this is not so, and at sea level a cubic foot of air weighs almost 1½ ounces. By comparison a cubic foot of hydrogen, the lightest of all gases, has merely one-sixteenth of this weight. A balloon full of hydrogen is therefore much lighter than the air that it displaces, and this is why it rises.

The envelope of a large airship contains several million cubic feet of hydrogen and weighs about 100 tons less than the air that it displaces. Thus not only can the airship fly, but it can lift a useful load. Furthermore, when an airship flies slightly 'nose-up', the skin acts as an aerofoil (like the wing of an aeroplane) and provides additional lifting force.

Two early airships

Though many had tried before him, Henri Giffard, a French engineer, was the first man to build an airship which really flew. His little craft, constructed in 1852, was 143 feet long, and 40 feet in diameter at its widest part. It was propelled by a 3-horsepower steam engine slung in a car 20 feet below the envelope (balloon). Giffard was his own pilot, and in an epic flight he flew his airship from Paris to Trappes, 17 miles away. His average speed was 5 miles an hour.



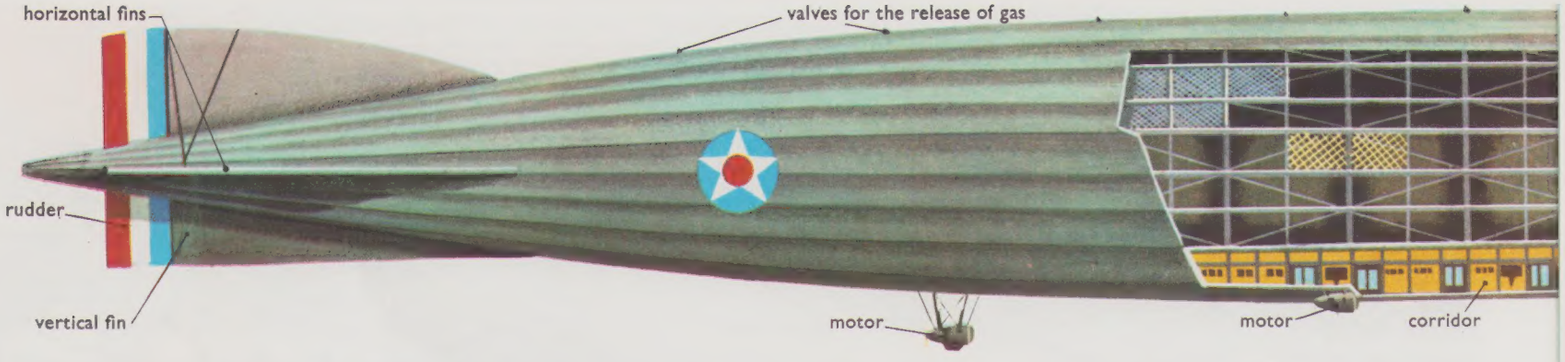
Henri Giffard's airship: the first dirigible ever to fly

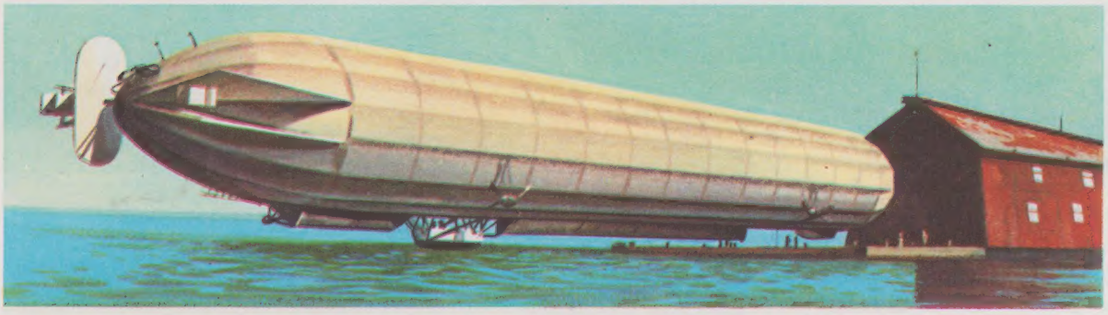
But although Giffard's airship was successful as far as it went, it was severely handicapped by the lack of a suitable power plant. His small steam engine had a very low power output for its weight, and the electric motors used in later airships suffered from a similar disadvantage.

The invention of the petrol engine, however, presented airship designers with a far superior method of propulsion. A wealthy young Brazilian living in Paris, Alberto Santos-Dumont, saw the potentialities of this new kind of engine and quickly decided to use one to propel an airship of his own design.

Santos-Dumont's fifth airship, which is said to have reached a speed of 52½ *miles an hour*

Santos-Dumont's airship was a great advance on all those built previously. It flew well and could be steered in any direction. Even so, the Brazilian was not satisfied. He embarked on the construction of a series of airships, and in 1901, with the sixth and best, he was able to make a round trip from the Paris suburb of St Cloud, around the Eiffel Tower, and back to his starting point. He covered the distance of 7 miles in 29 minutes 31 seconds, and won a prize of 125,000 francs.





The first rigid airship, LZ 1, leaving its hangar on Lake Constance prior to its first flight

The R 34. In July 1919 this fine British crossing of the Atlantic. It was also

Ferdinand von Zeppelin

Fourteen years before the famous flight of Santos-Dumont a lieutenant-general had been retired in disgrace from the German army. The severity of this punishment was such that any normal man would have been content to fade into obscurity, but not so Count Ferdinand von Zeppelin. At the age of 49 he sank his personal fortune in a new career which was to make his name a household word throughout the world.

Count Zeppelin founded a firm to build airships, but unlike those built by other designers his airships had rigid metal hulls. At first the design was not successful, and no less than seven of the first nine airships met disastrous ends. By 1913, however, several 'Zeppelins' were flying safely, and there were regular passenger services between six important German cities.

At the beginning of the First World War all German civilian airships were requisitioned for military use. These aircraft, and a further 62 which were built during the war, were operated chiefly by the German Naval Airship Service. They are remembered in Britain for the 51 air attacks which they carried out on various parts of the country, 12 of which were on London. Fortunately for the British public the Zeppelins proved an easy target for fighter aircraft, and so many were destroyed that the raids never constituted a serious threat.

DIRIGIBLE

The earliest lighter-than-air craft were merely balloons to which some form of passenger-carrying *basket* was attached. Without motors these craft were completely at the mercy of the wind, and their crews had no directional control whatsoever. With the advent of the petrol engine, however, lighter-than-air craft were fitted with propellers and thus made to move *through* the air. In consequence they became steerable, or *dirigible*.

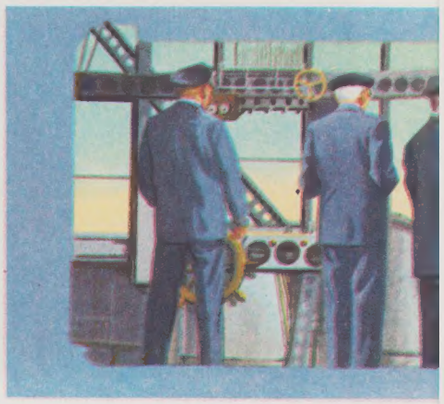
The word *dirigible* has often been used to signify only those airships with rigid hulls such as the *Graf Zeppelin*. Technically this usage is incorrect. The term includes any airship which can be steered, and thus, besides airships with rigid hulls, it includes two quite different types.

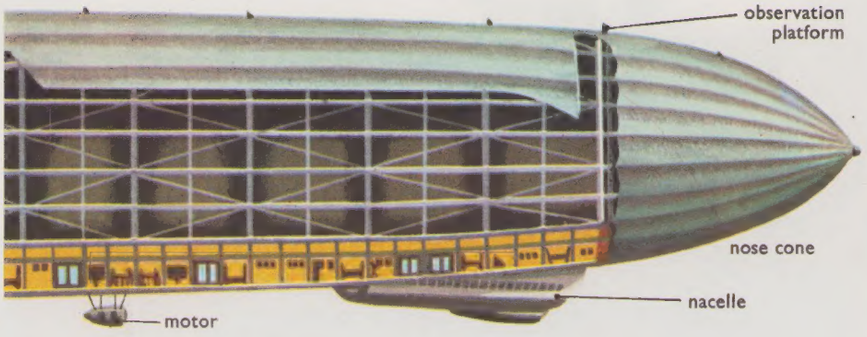
One is the non-rigid airship, the shape of which is maintained by the pressure of the gas within the envelope. The A-limps and B-limps (Blimps) of the First World War were of this type. The other airship type is the semi-rigid. In this the shape is maintained partly by gas pressure within the envelope and partly by the presence of a rigid 'keel' which runs along the underside of the airship.

British airships

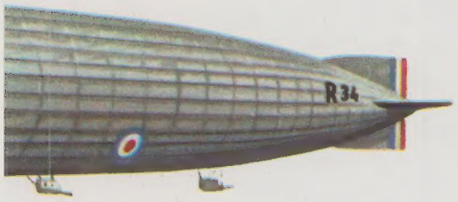
In the years before the First World War a small number of non-rigid (see below, left) airships was built and tested at Farnborough. One, the *Nulli Secundus*, caused a great sensation when, in 1907, it flew over the City of London.

During the war years the usefulness of non-rigid airships suddenly became apparent. Nearly 400 were built, and they were used to protect offshore convoys from attack by enemy submarines. It is estimated that British airships

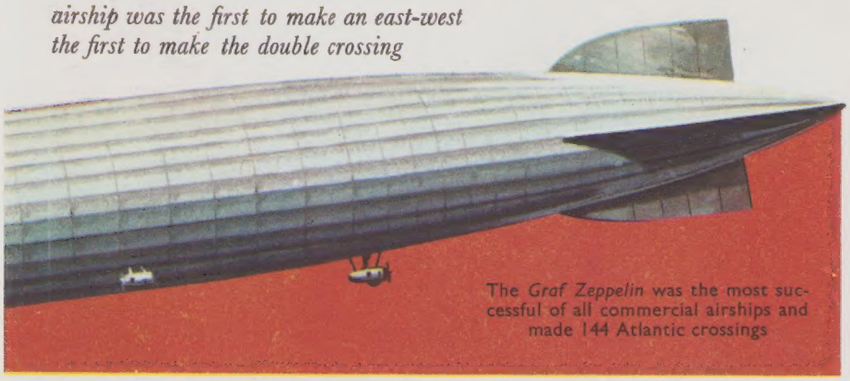




This cut-away shows the arrangement of the components of a large airship



airship was the first to make an east-west the first to make the double crossing



The *Graf Zeppelin* was the most successful of all commercial airships and made 144 Atlantic crossings

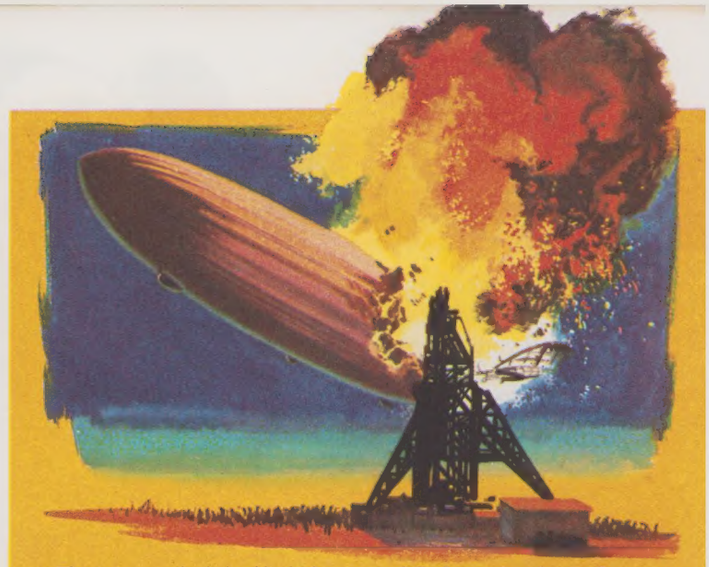
flew a total of $2\frac{1}{4}$ million miles with the loss of only 48 lives.

Experience with British rigid airships was much less satisfactory. Only one was built before the war, the *Mayfly*, and it never flew. It crashed against the side of its hangar and was damaged beyond repair. This loss dampened enthusiasm for rigid airships, and it was not until the end of the war that the second British rigid, the R 9, was completed. This, the first British rigid airship to fly, was not really successful. It was succeeded by the greatly improved R 23 and R 24.

A little later came the R 33 and R 34. These two airships were based on the design of the German LZ 65 shot down in Britain in 1916. Of all the airships built by the British, these were the most successful. In 1919 the R 34 made a double trip across the Atlantic, being the first airship to fly east-west and the first to fly both ways.

The sad fate of the R 100 and R 101 ends the story of British airships. These were two rigid airships built simultaneously between the years 1926 and 1930. Unfortunately the construction of the R 101 was bedevilled by political interference. Inadequately tested, it crashed in 1930 at Beauvais in France on its first flight with the loss of 46 lives. The R 100, a far better ship, thus became suspect too and was dismantled after its single, and very successful, voyage to Montreal and back.

The interior of the control cabin of a large airship. There is plenty of space for the crew to work, and the windows give an excellent view forward



The tragic end of the *Hindenburg* as it falls from the sky in flames at the end of its first Atlantic crossing on 6th May 1937

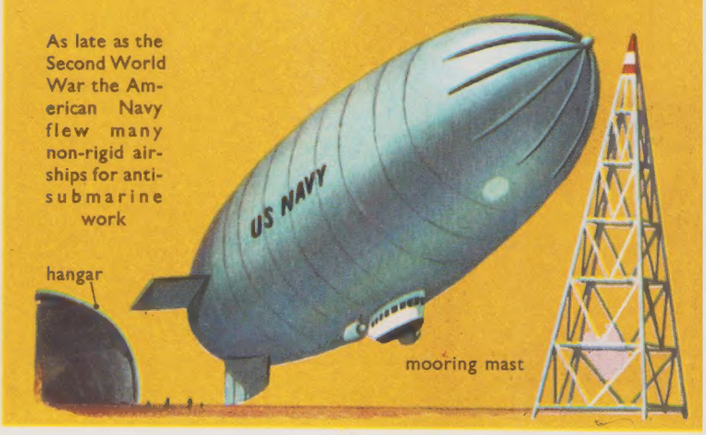
THE LAST AIRSHIPS

Long after all other countries had ceased to regard airships as a satisfactory form of passenger transport, Germany continued to operate the most successful airship of all time, the LZ 127, or *Graf Zeppelin*. This great rigid first flew in 1928. It was 775 feet long, its envelope contained 3,950,000 cubic feet of hydrogen, and its five engines gave a maximum speed of 60 miles an hour. Its carrying capacity across the Atlantic was 20 passengers and 12 tons of freight. During nine years of service its flying distance exceeded 1,000,000 miles, and it carried over 1,800 passengers.

So successful was the *Graf Zeppelin* that its German sponsors built an even larger airship, the LZ 129, known as the *Hindenburg*. Work on this 800-foot giant began in 1934 and was completed two years later. In May 1937 the *Hindenburg* made its first trip across the Atlantic to New York. On reaching Lakehurst the new Zeppelin was coming to the mooring mast when the rear part caught fire – within seconds the vast airship was destroyed. Miraculously, of the 100 people aboard only 35 lost their lives.

The disastrous fate of the *Hindenburg* ended the career of the *Graf Zeppelin*. The German authorities felt that they could no longer use such an inflammable gas as hydrogen for their airships, and they were unable to buy helium from America. The *Graf Zeppelin* was confined to its shed and later broken up for scrap.

After the loss of the *Hindenburg* the only country to operate airships was the United States of America. Her helium-filled non-rigid types performed wonderful anti-submarine work during the Second World War, and it is claimed that under their care not a single merchantman was lost.


As late as the Second World War the American Navy flew many non-rigid airships for anti-submarine work
US NAVY
hangar
mooring mast

THE URTICALES

IMAGINE a story, half fairy-tale, half science fiction, in which you are condemned to be exiled to an island on which grow all the plants of one botanical Order, but no other plants at all. There is an island for every Order, and you may choose which one you will go to. Rosales Island would be a good choice, for as well as roses many edible fruits belong to this Order. However, Urticales Island would offer some excellent fruits and a variety of useful products as well. This is rather surprising, since the most characteristic plant of this Order, from which it takes its name, is *Urtica*, the nettle.

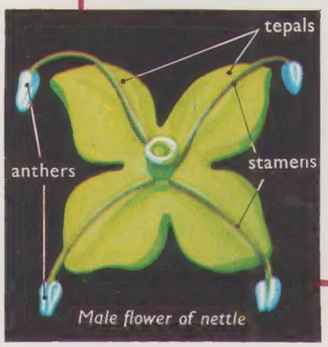
On Urticales Island you would find not only nettles, but figs and mulberries with their delicious fruit. Possibly there would be silkworms feeding on the mulberry leaves. Indian hemp and ramie would be growing there, both of which plants yield useful fibres. Hops would grow on the island, and although you would not be able to make beer from them (you would have no barley for malting), you would find that hops have a pleasant fragrance and are very ornamental. Although there would be a total absence of brightly coloured flowers, many of the other plants would be ornamental too. There would be no lack of trees, for as well as the mulberry and fig trees there would be elms for timber, and several of the trees from which rubber is produced.

ABOUT 2,000 SPECIES

Most of the Orders of the Vegetable Kingdom (see page 599) consist of plants which look somewhat alike, so that we can see why they are grouped together, but the 2,000-odd species of the Urticales are extremely diverse; what have the nettle, the hop, and the elm to do with each other?

The answer is that their flowers are all constructed on a similar plan. The calyx and corolla are not distinct, as the petals and sepals look the same, and are both called 'tepals'. The flowers of the Urticales have four to six tepals and always the same number of stamens. The ovary is superior (see page 1046), containing one ovule which develops into a fruit that is either an achene or a drupe (see page 1954).

The Order is divided into four Families, each of which has the characters of the Order, and in addition each one has detailed characters of its own. The Families are: *Urticaceae*, including the nettles; *Ulmaceae*, elm trees; *Cannabinaceae*, the hemp Family; and *Moraceae*, the mulberry and figs. We shall describe the last Family in a separate article.

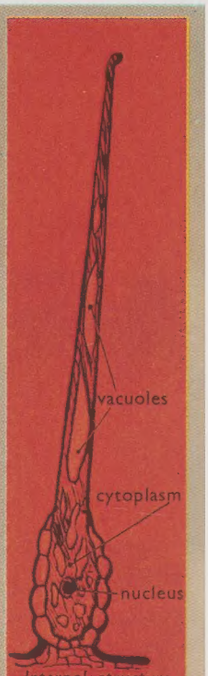


Male flower of nettle

Nettle plant with male flowers

URTICACEAE

These are the nettles and include over 500 species. The name is derived from the Latin, *urere*, to burn, and refers to the nettles' property of stinging. Probably everyone has been stung by nettles at some time; the sting of the common European ones is not very painful, but some of the tropical species sting much more severely.



Internal structure of a nettle sting

Stinging nettle (*Urtica dioica*). The illustration above shows how the sting of a nettle works. The leaves and stems are covered with hairs which have very sharp tips, hardened with silica, the mineral used in glass-making. The lower part of the hair has spaces or vacuoles containing an irritant poison. When the hairs touch your skin the sharp, brittle tips pierce it and break off, and the poison is injected.

Leaves of Boehmeria nivea

A textile-producing nettle, the ramie or China grass (*Boehmeria nivea*). This plant is cultivated in China, Japan, and India for the sake of the fibre it produces. These fibres are very strong, and can be separated almost to the fineness of silk by mechanical and chemical processing methods. They are used for making gas mantles and parachute cordage, and also for weaving into a fabric which is rather like linen. At one time ordinary nettles were also used to produce fibre.

ULMACEAE

This is a Family consisting of trees and shrubs, most of which are found in the northern temperate and subtropical regions. It includes about 150 species, of which the elm trees (*Ulmus*) are the best known.

A medicinal nettle, wall-pellitory (*Parietaria diffusa*). This is a stingless type of nettle found growing on old walls and quite common in Britain. The leaves are glossy, and the stem is covered with hairs, but these are not stinging hairs. The flowers are tiny and greenish with yellow anthers. An infusion of the plant was formerly used as a diuretic (for draining body fluid).

Leaves and flowers of wall-pellitory

An ornamental nettle (*Pilea cadieri*). The genus *Pilea* includes about 200 species which are native to tropical America and south-east Asia. In recent years some of them have been introduced to Europe as ornamental plants. *Pilea cadieri* has large leaves with broad, silvery marks between the veins.

Leaves and flowers of Pilea

CANNABINACEAE. This is a small Family, but it includes two plants of great economic importance – the hop and hemp. The plants contain oils and resins which may be strongly flavoured or act as a narcotic.

Leaves and female flowers of hemp

Leaves and female flowers of hop

Hemp (*Cannabis sativa*). This is a plant growing about 8 feet high, with leaves divided into five leaflets, like the fingers of a hand. It is a native of India and Persia and is cultivated for the sake of its fibres, from which canvas and rope are made. The dangerous drug hashish, or marijuana, is also a product of hemp.

Hop (*Humulus lupulus*). This is a climbing plant which grows wild in Britain and is also cultivated on a very large scale for use in flavouring beer. The cultivation involves the erection of large numbers of poles interlaced with twine for the plants to climb on. In Britain hops are an important crop, mainly in south-eastern England. The male and female flowers are borne on separate plants, and the female inflorescences, which are shaped like pine-cones, are the actual hops used in the brewing industry to give beer its bitter taste. Until recently hop-picking was done by hand, but it is now very largely mechanised.

Elms (*Ulmus*). The elms are all large trees with rough bark and characteristic leaves; these are oval with toothed edges, and are asymmetrical at the base. The species are hard to distinguish because there is much hybridisation among them.

In Britain two are generally recognised: the common elm (*Ulmus procera*), with smaller leaves and the habit of throwing up subsidiary bushes or 'suckers' from its roots; and the wych elm, with larger leaves and few or no suckers. The common elm often grows to a great height; its specific name (*procera*) means 'tall'. The timber is valuable because it resists decay under water and is used for piers and jetties.

Leaf of elm

Fruit of elm

A fine specimen of the common elm

THE HISTORY OF RELIGIOUS

'CROMWELL REPORT MEANS MONASTERIES MUST GO

Stately Fanes for Earthly Gains'

IF there had been popular daily newspapers, so might have read the 16th-century headlines on the eve of the dissolution of the English monasteries, which began in earnest in 1536. Henry VIII was in desperate need of money, and a large-scale take-over of church property was one way out of his financial straits. But English monasticism was dying anyway – although the monks were not so much slack or decadent as lukewarm. The burning ideals and sincerity of the early Middle Ages had vanished. Monasteries whose names were once revered – Fountains (see page 998), Glastonbury, Tintern, Sherborne – were but pale shadows of their former selves.

The monks and nuns inside these monasteries were members of religious orders: Benedictines, Cluniacs, Cistercians, Carthusians, and so on. The orders were not dissolved like the monasteries. Indeed more have been founded since the Dissolution, and today they are still a very important part of the Christian Church. But in this article we are only going to look at the history of the religious orders in the Middle Ages – a story that begins in the Egyptian desert and ends with the insistent questioning of Thomas Cromwell's commissioners before the Dissolution.

What is a religious order?

A full member of a religious order must take the three vows of poverty, chastity, and obedience, and observe the rule or constitution of his order. The order may be *monastic* (from the Greek, *monos*, alone) – that means the monk or nun lives in a monastery, and is cut off from the outside world to a greater or lesser degree; or it may be *non-monastic*, in which case its members seek to serve God by working in the world.

There had been monasticism before the birth of Christ – in Judea and Egypt, for example – but the first Christian monks were probably not greatly influenced by it. The first important name in Christian monasticism is **St Antony the Hermit,** who, at the beginning of the 4th century, led a solitary life with a group of disciples in the north Egyptian desert. This group was more a collection of hermits than a community, but it was the beginning of one of the great monastic traditions – the *eremetic* (hermit-like) tradition. The *coenobitic* (living together) tradition, in which the monks served God by living a communal life under a single rule, began in southern Egypt with **St Pachomius.** Before his death in A D 346 Pachomius had established nine monasteries of men and one of women. At the beginning of the next century there were about 7,000 Pachomian monks.

Another great monastic tradition was begun by the foundation in the middle of the 4th century of the monastery of Pontus in Asia Minor by **St Basil.** This was the beginning of the monasticism of the Greek Orthodox Church (see page 1312).

Monasticism found a foothold in Europe with **St Athanasius,** who arrived in Rome in 339 or 340 with two monks. It soon spread throughout Italy and Gaul. However, it was not until the time of **St Benedict of Nursia** (c.480–c.550; see page 1526) that a rule was produced that was really suitable for Europeans. The eastern tradition had been fiercely *ascetic* (laying stress on extreme bodily privation), and only the strongest could stand it. St Benedict's Rule was more realistic, although still very strict. He organised the monastic day into sections for religious observance, prayer, devotional reading, and work. His Rule bound both monks and abbot (the head of the monastery, from the Syriac, *abba*, father). Moreover, he also introduced the rule that a monk must stick to his monastery for his life. The most important part of the monk's life was the daily round of religious observance, in and out of church. The Benedictines spread rapidly through Europe, and their Rule had only one 'rival', the Rule of the Irish monk, **St Columbanus** (c.550–615). It was much more ascetic and eremetic than the Rule of St Benedict: 'Let a man go to bed when he sleeps on his feet before reaching it . . .' it laid down. But the Rule of St Benedict gradually supplanted that of St Columbanus over most of Europe.

During the Dark Ages there were many adaptations of the Rule of St Benedict. In England there was the *Regularis Concordia* (the agreement on rule), drawn up in 970 by **St Dunstan** and St Ethelwald. This played an important part in the English monastic revival of the 10th century (see page 1068).

One of the most famous of the adaptations of the Rule of St Benedict was that of **Cluny.** This monastery was founded in Burgundy in 910, and soon many monasteries began to adopt its interpretation of the Rule. In 1048, on the death of Cluny's fifth abbot, St Odilo, Cluny was at the head of a powerful monastic empire. One particular feature of the Cluniac constitution was the length of time that had to be spent in choir and on religious ceremonies. This was at the expense of manual work. The order became immensely rich and powerful. Although one can talk about the Order of St Benedict with reference to all monks who followed his Rule in one way or another, the Cluniacs might be described as the first separate order.

But while Cluny was at the height of its power, Europe saw the beginnings of a revival of the eremetic and ascetic spirit. In the 12th century two orders in particular came to the fore which were expressions of it: the Order of the Grande Chartreuse (the Carthusian Order, founded 1084) and the Order of Cîteaux (Cistercian Order, founded 1098–1100). The Rule (or Customs) of the **Carthusian Order** was a com-

MEMBERS OF RELIGIOUS ORDERS TODAY

Benedictine *Cistercian*

bination of the Rule of St Benedict and early ascetic and eremetic ideals. The monks were vowed to silence, and lived in separate cells inside the monastery. Their life was one of private prayer and meditation; the other brethren were only seen inside the church for religious ceremonies and at a communal meal on feast days.

The **Cistercian Order** was, in contrast, coenobitic, but almost as ascetic as the Carthusian. The Cistercians returned to the original interpretation of the Rule of St Benedict, which had, by this time, many modifications.

The Cistercians were lucky in that one of the early members of their order was **St Bernard of Clairvaux** (1090–1153). He was one of the most remarkable personalities of the Middle Ages. Kings, Popes, cardinals, and archbishops were often the worried recipients of his peremptory letters telling them how to do their jobs. He interfered with papal elections, launched a crusade himself, and was treated as a saint in his lifetime. Needless to say, with such powerful backing the Cistercian abbeys spread rapidly, and before the end of the 12th century there were 530 of them in Europe.

St Bernard was in the forefront of the controversy that arose between the Cistercians and the Cluniacs. St Bernard considered the Cluniacs had departed from the spirit of the Rule of St Benedict. He thought a monk's soul was stifled by the magnificent ceremonies of Cluny. He believed a monk needed to be alone to learn how to love God properly. Moreover, he objected to the splendour of the Cluniac life, and the none too strict rules. He seems to have been especially perturbed by the good food at Cluny. 'The soul,' he thundered, 'is not fattened out of frying pans.'

Dominican

The 12th century also saw the growth of two other important religious orders: the **Canons Regular** (or Augustinian Canons, clergy living a semi-monastic life according to the 'Rule of St Augustine'), and the **Military Orders** like the Knights Hospitallers, Knights Templars, and Teutonic Knights (see page 2166).

In the first half of the 13th century there appeared a completely new type of religious order – the **mendicants.** These were the Franciscans (founded in 1209), the Dominicans (1215), the Carmelites (1245), and the Augustinian Hermits (1256). Of these the best known are the Franciscans and Dominicans.

The **Franciscans** were founded by St Francis of Assisi (see page 406). He insisted on complete poverty. The Franciscans were to receive no money but to live by the work of their hands or by begging (hence the word mendicant, from the Latin, *mendicare*, to beg). They were to wander through Europe spreading the simple Gospel of Christ and have no monastery or roof over their head that they could call their own. The **Dominicans,** founded by St Dominic (see page 998), were similar to the Franciscans in their insistence on complete poverty. They were allowed convents to live in, but these had to be supported by begging. The order was particularly dedicated to preaching and study, and came very much to the fore in combating heresies which appeared in the 13th century.

Both orders quickly went into a decline and were rent by internal squabbles. The Franciscans were divided into two parties. One insisted on observing the letter of the Rule of St Francis; the other thought it should be revised to fit in with the times, and that the Franciscans should have settled houses or convents to live in. The quarrel between the *observants* and the *conventualists*, as they came to be called, lasted well into the 14th century. The Dominicans suffered a similar decline. Indeed this century saw a decline in religious orders as a whole – and by the 16th century there were many who felt that the orders no longer deserved the privileged position they had held in the life of the nation, and what Cromwell was doing for money in England, they would do from principle.

FRIARS TODAY

THE WOMAN'S PART

In the Middle Ages monks outnumbered nuns (female monastics). Today it is the other way round. But nuns have always played an important part in monasticism. Sisters of St Pachomius, St Basil, and St Benedict ruled over communities whose rules were adaptations of those of their brothers. Most mediaeval monastic and mendicant orders had a female branch, like the Dominican nuns and Poor Clares (Franciscan nuns). There were also double orders – monks and nuns who shared the same monasteries. In these the nuns were usually dominant. In England there was the famous double order of Sempringham.

TITLES

THE after-dinner speaker gets to his feet. 'My lords, ladies, and gentlemen,' he begins, surveying an audience which is made up of peers, bishops, government officials, members of the orders of knighthood, and service personnel. If he addressed each one personally, according to his rank and title, the speaker's introductory remarks might well last for half an hour. For the people in his audience all bear 'those various names of greatness or eminency, the most distinguishing titles of civil dignity' which show their status in society or rank in their particular walk of life. Some of them have 'personal' titles, inherited from their ancestors; others have 'official' titles, bestowed upon them by the sovereign, showing the position they hold in civil or military life, and not conferring the same style as a 'personal' title; a third group may have received their titles or honours as a reward for loyal service. Some even hold all three kinds of title.

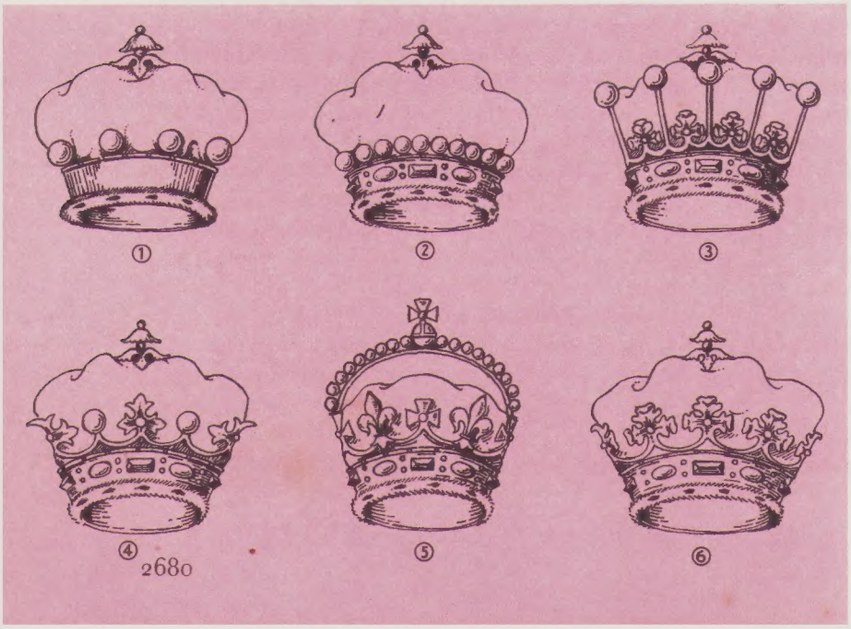
Personal titles

The peerage, or true nobility, of the United Kingdom has five ranks, after the royal family. They are, in order of priority: duke, marquess, earl, viscount, and baron. These titles are all hereditary except, of course, those conferred as life peerages by the Crown. So far no life peer has been created above the rank of baron. Of lesser title-holders, baronetcies are hereditary but knighthoods are not.

Officially, only the holder of one of the five noble titles is a peer. Although his wife takes the same rank, his children are commoners. If the peer has several titles, however, a lesser one is given to his heir as a 'courtesy title' until he inherits the peerage; other members of the family usually also have courtesy titles. They do not legally own these titles, however, and in official documents their proper names would be given; for example, 'John Smith, commonly known as the Marquess of Northtown', for the heir to a dukedom.

Some peerages can only be passed on to a male heir, but there are in the United Kingdom today 25 peeresses in their own right, who have succeeded to noble titles or have been made life peeresses. These peeresses rank with the peers in the order of precedence (see far right) and can pass their title on to an heir, male or female, except in the case of life peeresses.

Crowns and coronets of the nobility, worn only on ceremonial occasions such as a coronation, by ① Baron, ② Viscount, ③ Earl, ④ Marquess, ⑤ Heir Apparent to the throne, and ⑥ Duke



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Orders of honour

The orders of knighthood and honour (see page 2166) are also personal titles, conferred by the sovereign. They cannot be passed on to an heir, nor do they bestow any rank or title upon the holder's family, except in the case of knighthood, when the wife becomes 'Lady'. Even if such an award does not carry the rank of knight the holder is still entitled to put the initials of the order after his name.

Royal peerages

Since Norman times the sovereign has been able to confer a peerage on members of his family, as well as on his subjects. Some of these royal peerages have become traditional; for example, the male heir apparent to the throne is automatically Duke of Cornwall, since Edward III's son, the Black Prince, who was also created Prince of Wales by his father in 1343. The heir apparent is also Earl of Chester (since Henry III's time). These latter titles are re-created for each heir apparent who is usually invested as Prince of Wales at a special ceremony.

Other members of the royal family have received dukedoms in the past, some of which have now passed out of the royal circle. More recently created dukedoms have been kept within the royal family.

The dukedom of Rothesay was the first Scottish royal peerage, created in 1398. This title, together with the earldom of Carrick, the barony of Renfrew, and the titles of Lord of the Isles, and Prince and Great Steward of Scotland, pass automatically to the heir apparent.

Official titles

Lord Privy Seal, Master of the Rolls, Judge, Major-General, Sub-Lieutenant: these are all examples of official titles which accompany the post to which the holder has been appointed. None of them give any special privileges or title to the holder's family.

Order of precedence

When holders of both personal and official titles meet, who are the most important? Who goes first, the duke or the Prime Minister? The answer is given in the order of precedence; that for men on ceremonial occasions in England is given on the far right.

The order of precedence is the official order of priority of all title- and office-holders in the United Kingdom that has grown up over the centuries, based on 'royal pleasure, ancient usage, and statute'. The 'royal pleasure' has been greatly limited over the centuries, particularly by the Bill of Rights (1689). The sovereign can still create new peers and award knighthoods but cannot 'promote' anyone to a higher position in the order of priority – those created first come before later additions in the same rank.

The correct order of priority within each rank of the peerage is: first, those created in England before 1707; secondly, those created in Scotland before 1707; thirdly, those created between 1707 and 1800, and known as peers of Great Britain; and lastly, those created since 1801, known as peers of the United Kingdom.

It sometimes happens that someone has more than one title, either personal, or official, or both; if this is the case, then he takes his order of precedence from his highest title. For example, if a Commander of the Order of the British Empire was appointed High Commissioner for a Commonwealth country, he would take his place among the High Commissioners and Ambassadors, not among the C B E holders.

	Written address	*Spoken address*
Ambassador, British	His Excellency (any other rank) H.B.M.'s Ambassador and Plenipotentiary. *Begin:* Sir or according to rank	Your Excellency
Archbishop	His Grace the Lord Archbishop of —. *Begin:* My Lord Archbishop	Your Grace
Baron	The Right Hon. Lord —, or The Lord —. *Begin:* My Lord	Your Lordship
Baroness	The Right Hon. the Baroness —, or The Right Hon. Lady —. *Begin:* My Lady	Your Ladyship
Baronet	Sir John Smith, Bt. *Begin:* Sir	Sir John
Baronet's wife	Lady Smith. *Begin:* Madam	Your Ladyship
Bishop (Diocesan)	The Right Rev. the Lord Bishop of —. *Begin:* My Lord Bishop	Your Lordship
Clergy	The Rev. James Brown. *Begin:* Rev. Sir	Mr. Brown
Countess	The Right Hon. the Countess of —. *Begin:* Madam	Your Ladyship
Duchess	Her Grace the Duchess of —. *Begin:* Madam	Your Grace
Duke	His Grace the Duke of —. *Begin:* My Lord Duke	Your Grace
Earl	The Right Hon. the Earl of —, or The Earl of —. *Begin:* My Lord	Your Lordship
Judge (English)	The Hon. Sir John Black (if a knight) or The Hon. Mr. Justice Black. *Begin:* Sir	(when on bench) Your Lordship
Knight	If of an order of chivalry: Sir James Young+initials of order. If Knight Bachelor: Sir James Young. *Begin:* Sir	Sir James
Marchioness	The Most Hon. the Marchioness of —. *Begin:* Madam	Your Ladyship
Marquess	The Most Hon. the Marquess of —. *Begin:* My Lord Marquess	Your Lordship
Prince	If a duke: His Royal Highness the Duke of —. If not: His Royal Highness Prince John. *Begin:* Sir	Your Royal Highness
Princess	If a duchess: Her Royal Highness the Duchess of —. If not: Her Royal Highness the Princess Jane. *Begin:* Madam	Your Royal Highness
Queen	The Queen's Most Excellent Majesty. *Begin:* Madam, or, May it please Your Majesty	Your Majesty
Viscount	The Right Hon. Viscount —, or Viscount —. *Begin:* My Lord	Your Lordship
Viscountess	The Right Hon. the Viscountess —, or The Viscountess —. *Begin:* Madam	Your Ladyship

The order of precedence shown on the right is that for men, and applies only to England. Among women, wives of peers generally take the same rank as their husbands; unmarried daughters of peers follow the order of priority of their brothers.

Forms of address

There is a special way of addressing the holders of certain titles. The correct way to write or speak to a peer or his family is given above.

The nobility

Few monarchies survive today with the power to perpetuate or create noble titles. Outside the United Kingdom, the nobility includes anyone with a personal title, but has little prestige and less power; in some republics or socialist states noble titles have been abolished and replaced by military or academic honours.

The chief titles of nobility in France are *duc*, *marquis*, *comte*, *vicomte*, and *baron*. Those without a title were considered *chevaliers* or knights. The many strata within the nobility, from the *gentilhomme* up to the *grand seigneur*, were clearly defined, and between them they governed France and led her armed forces before the French Revolution. The nobility has been restored since the Revolution, but of course without the same power.

German nobility, too, had several layers; the princely families, or *Hohe Adel*, included the duke (*Herzog*), prince (*Fürst*), marquess (*Markgraf*), and some counts (*Graf*). The *Niedere Adel*, or lesser peers, were the baron (*Freiherr*) and knight (*Ritter*), who usually had the prefix 'von'.

The nobility of France and Germany drew their titles and prestige mainly from their lands and country estates. The Italian nobles, on the other hand, were principally town-dwellers, most of whom held public offices from which their titles were derived.

In Germany, Austria, Sweden, Denmark, Holland, and Belgium all members of noble families, male or female, have the title prince or princess, count or countess, and so on.

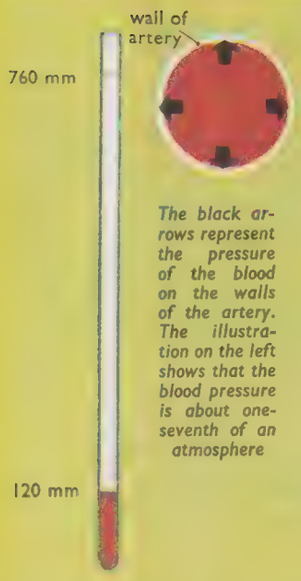
Noblesse oblige

The holder of a title in the United Kingdom, if not elsewhere, has certain privileges and is treated with respect. But since earliest times a title has carried with it certain responsibilities as well: the leader has a duty to his followers, the landowner to his tenants, and the officer of the Crown to his employer and the nation.

MALE ORDER OF PRECEDENCE IN ENGLAND (after the Queen)

The Prince Philip, Duke of Edinburgh
The Prince of Wales
The Prince Andrew
The Duke of Gloucester
The Duke of Kent
The Duke of Windsor
Archbishop of Canterbury
Lord High Chancellor
Archbishop of York
The Prime Minister
Lord President of the Council
Speaker of the House of Commons
Lord Privy Seal
High Commissioners of Commonwealth Countries and Ambassadors of Foreign States
Dukes in order of creation: 1st, of England (created before 1707); 2nd, of Scotland (created before 1707); 3rd, of Great Britain (created from 1707 to 1800); 4th, of the United Kingdom (created after 1800)
Ministers and Envoys
Eldest sons of Royal Dukes
Marquesses
Dukes' eldest sons
Earls
Younger sons of Royal Dukes
Marquesses' eldest sons
Dukes' younger sons
Viscounts
Earls' eldest sons
Marquesses' younger sons
Bishops of London, Durham, and Winchester
All other English Bishops
Secretaries of State (if Barons)
Barons
Treasurer of H.M.'s Household
Comptroller of H.M.'s Household
Vice-Chamberlain of H.M.'s Household
Secretaries of State
Viscounts' eldest sons
Earls' younger sons
Barons' eldest sons
Knights of the Garter (if commoners)
Privy Councillors
Chancellor of the Exchequer
Chancellor of the Duchy of Lancaster
Lord Chief Justice of England
Master of the Rolls
President of the Probate Court
The Lords Justices of Appeal
Judges of the High Court
Vice-Chancellor of County Palatine of Lancaster
Viscounts' younger sons
Barons' younger sons
Sons of Life Peers
Baronets
Knights of the Thistle (if commoners)
Knights Grand Cross of the Order of the Bath
Members of the Order of Merit
Knights Grand Commanders of the Star of India
Knights Grand Cross of St Michael and St George
Knights Grand Commanders of the Indian Empire
Knights Grand Cross of the Royal Victorian Order
Knights Grand Cross of Order of the British Empire
Companions of Honour
Knights Commanders of the above Orders
Knights Bachelor
Official Referees of the Supreme Court
Judges of County Courts, and of the Mayor's and City of London Court
Masters in Lunacy
Companions and Commanders of Orders
Eldest sons of younger sons of Peers
Baronets' eldest sons
Eldest sons of Knights
Younger sons of the younger sons of Peers
Baronets' younger sons
Younger sons of Knights
Naval, Military, Air, and other Esquires in order of office or rank

BLOOD PRESSURE



The black arrows represent the pressure of the blood on the walls of the artery. The illustration on the left shows that the blood pressure is about one-seventh of an atmosphere

CUT yourself, and the wound bleeds. It does so because the blood within the tiny capillaries of the skin is under pressure, and the cut provides a route by which it may escape. The amount of blood lost is usually small, for the blood pressure in the capillaries is low. If, however, an artery is cut, the wound bleeds furiously because the blood pressure in large vessels is much greater.

The pressure of the blood within the circulatory system serves two purposes. First, it impels some of the circulating blood upwards against gravity into the carotid arteries, and so ensures a supply of blood to the brain. Secondly, it forces blood through the tiny capillaries in the tissues. These vessels are so narrow that without considerable arterial pressure the blood flow through them would be negligible.

HOW THE BLOOD PRESSURE IS MAINTAINED

The maintenance of the pressure of the blood within the arteries is an exceedingly complex physiological process. Basically it depends on three factors which, under nervous control, keep the pressure relatively constant.

First, the beating of the heart is continually pumping blood into the aorta. This blood flows along the large arteries and into the smaller vessels, where it replaces the blood escaping through the capillaries into the veins. In this way the *volume* of blood in the arterial system is maintained.

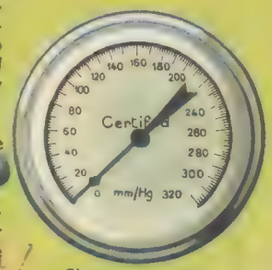
In a rigid artery the systolic pressure would be very high. In diastole it would fall considerably

In an elastic artery the systolic pressure is accommodated. Contraction during diastole maintains the pressure

Secondly, the walls of the arteries contain muscle and elastic fibres. Each time that the heart beats and discharges blood into the arterial system, these fibres stretch to accommodate the influx of blood. When the heart relaxes, on the other hand, the fibres in the walls of the vessels contract, and by so doing they not only reduce the capacity of the circulatory system but also maintain the pressure.

Thirdly, and lastly, the minute arterial vessels, the *arterioles*, which lead from the smallest arteries to the capillaries, have muscular walls. Contraction of these muscles reduces the blood flow through the capillaries, and so controls the rate at which it escapes from the arterial system, through the capillaries, and into the veins.

A modern sphygmomanometer enables a doctor to measure the blood pressure in a few moments



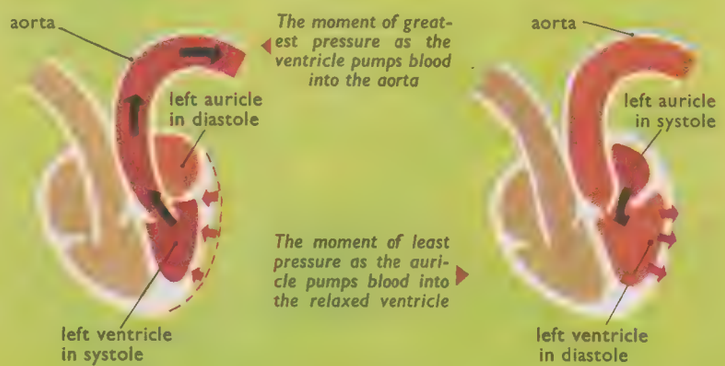
Close-up view of a typical sphygmomanometer

THE PARSON AND THE MARE

The first man to measure the pressure of the blood was a scientifically minded parson, the Reverend Stephen Hales of Teddington. He performed his experiment in 1679, 51 years after Harvey had described the principles of the circulation (see page 218). In his experiment Hales used a small metal pipe to which was attached, by means of a goose's wind-pipe, a 9-foot length of glass tubing. With the glass tubing held vertically, the free end of the metal pipe was inserted into the femoral artery of a mare. Blood immediately flowed into the glass tube and, after a few moments, reached a height of 8 feet 3 inches. This demonstrated that the pressure of the blood in the femoral artery of the mare was sufficient to support a column of blood 8 feet 3 inches long. Moreover, the level rose and fell a little with each beat of the mare's heart. The contraction of the heart (known as *systole*) pumped out blood and the pressure rose; and as the heart relaxed (in *diastole*) the pressure fell back a few inches.

This diagram shows the blood pressure in a large artery, an arteriole, a venule, and the vena cava

If the same experiment were to be performed on a healthy man the column of blood would be much shorter. Indeed, the blood pressure of a human being will support a column of only 4 feet 6 inches long. In practice it is the custom to measure the blood pressure against a column of mercury rather than of blood, and to express the result as the number of millimetres of mercury supported.


aorta
left auricle in diastole
left ventricle in systole
The moment of greatest pressure as the ventricle pumps blood into the aorta
The moment of least pressure as the auricle pumps blood into the relaxed ventricle
aorta
left auricle in systole
left ventricle in diastole

MEASURING HUMAN BLOOD PRESSURE

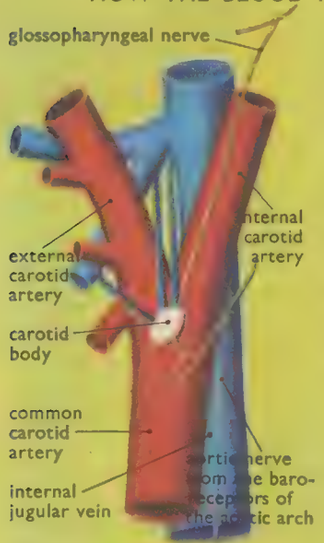
Although the direct way of measuring blood pressure used by Hales was excellent in its way, it is obviously unsuitable for use in humans. Fortunately the *sphygmomanometer* provides a much more practical and less damaging method.

Around the upper arm is wrapped an inflatable sausage-shaped cuff to which is attached some form of pressure-measuring device, such as a mercury manometer or a small pressure gauge. When all is ready the pulse is felt at the wrist and air is gently pumped into the cuff. As the pressure rises the pulse quite suddenly disappears. It does so when the pressure in the cuff is sufficient to compress the brachial artery quite flat, so that blood can no longer reach the wrist. At this point the gauge reads the systolic pressure. In a healthy human this lies between 100 and 160 millimetres of mercury.

A little more skill is needed to determine the diastolic pressure. The usual method is to blow up the cuff until the pulse at the wrist is obliterated. The valve on the cuff is then loosened a little so that the air escapes very slowly. While this is happening a stethoscope is applied to the front of the elbow. As the pressure in the cuff falls a characteristic series of sounds is heard, and then silence. At this point the gauge registers the diastolic pressure. Depending, like the systolic pressure, on the subject's age, the diastolic pressure is likely to lie between 60 and 100 millimetres of mercury.

A difficulty in measuring human blood pressure is that the procedure may at first alarm the patient, and this in itself is enough to raise the pressure. For this reason it is often taken twice, at the beginning and end of a medical examination.

HOW THE BLOOD PRESSURE IS CONTROLLED



The site of the carotid sinus and the carotid body at the bifurcation of the common carotid artery

In the arch of the aorta, and in that part of the carotid artery just below the bifurcation known as the *carotid sinus*, there are a number of small sense organs called *baroreceptors*. These organs are sensitive to the pressure of the blood in the two large vessels, and their function is to discharge nerve impulses, which, passing along the aortic and glossopharyngeal nerves, report this pressure to the *vasomotor centre* in the medulla oblongata.

In response to the sensory messages the vasomotor centre discharges impulses along the nerves of the autonomic system (see page 2440) to correct any deviations from the normal pressure. Thus, should the pressure fall, the force and rate of the heart-beat are increased so that more blood is pumped into the arteries. At the same time the arterioles contract to reduce the rate at which the blood escapes into the veins. An increase in pressure has the opposite effect.

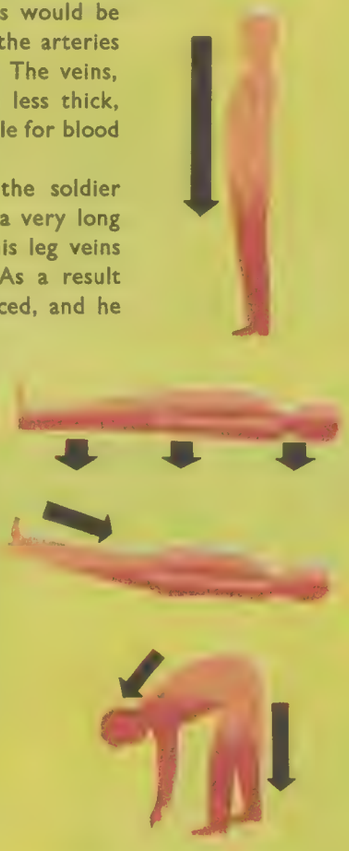
Besides the baroreceptors there are also *chemoreceptors*. There are two of these organs: the *aortic body* in the arch of the aorta and the *carotid body* near the bifurcation of the carotid artery. They have a rich supply of blood and their function is to 'sense' the amount of carbon dioxide that it contains. When the carbon dioxide content rises the respiration rate increases to wash out the unwanted gas, and at the same time the rate and force of the heart-beat is increased.

THE EFFECTS OF POSTURE

If there were no mechanism for maintaining the blood pressure, all the blood would rapidly gravitate to the lowest parts of the body, and situations like those in these illustrations would arise. The blood vessels in some parts of the body would be completely filled with blood, while those in other parts would be quite empty. Fortunately the walls of the arteries are so strong that this cannot happen. The veins, however, have walls which are much less thick, and under certain conditions it is possible for blood to stagnate in them.

A well-known example occurs in the soldier who is kept standing at attention for a very long time. So much blood accumulates in his leg veins that too little returns to his heart. As a result the blood supply to his brain is reduced, and he faints.

Another example is familiar to everyone who likes hot baths. The heat of the water brings about relaxation of arterioles both in the skin and in the internal organs. Thus, though a man may feel quite well when lying down in the bath, when he stands up his blood pressure is insufficient to ensure the usual supply of blood to the brain. In consequence he feels dizzy.



These diagrams show how the blood would gravitate to the lowest parts of the body were the blood pressure not maintained by the action of the heart and arterioles

HAEMORRHAGE

In a serious accident it is not unusual for one or more large blood vessels to be damaged, and for a haemorrhage (severe bleeding) to take place. The amount of blood circulating in the body is greatly reduced. In these circumstances the blood pressure tends to fall, and as it does so compensatory mechanisms come into play to keep it as near normal as possible, and thus to maintain the supply of blood to the most important parts of the body.

Impulses from the baroreceptors of the aortic arch and the carotid sinus signal the fall in pressure to the vasomotor centre. In response the centre sends messages along the vagus nerve to increase the rate and the force of the heart-beat. At the same time other messages passing out along the sympathetic nerves bring about contraction of the arterioles in the skin, which impedes the flow of blood through the peripheral vessels, and in consequence the skin turns pale. Furthermore, the spleen contracts, and in doing so forces its store of blood into the circulation.

In this way the body attempts to maintain life by keeping up the pressure of the blood that remains within the circulatory system. It cannot, of course, compensate for a really vast haemorrhage – for example, from a bullet wound of the aorta – but it is sufficient to sustain life after loss of even as much as half of the blood volume.

CAESAR AND THE CONQUEST OF GAUL

IN 58 B C, after his year as consul, Julius Caesar left Rome to take up his military command in the provinces. As he wanted to control the armies nearest Rome, he had demanded the provinces of Illyricum (Yugoslavia) and Gallia Cisalpina (North Italy) for five years. The Senate had also given him Gallia Transalpina (Gaul beyond the Alps). Perhaps Caesar's opponents expected the task would be beyond his powers, and hoped he would suffer a humiliating defeat; for Caesar, now 41 years old, had not yet shown signs of his military genius.

Gallia Transalpina was divided between tribes of three Celtic races: the Belgae in the north-east (and also in south-east Britain); the Aquitani in the south-

west; and the Gauls proper (or Celtae) in the centre. The Romans had conquered south-east Gaul in 121 B C. This, 'the Province' (modern Provence), was centred on Narbo (Narbonne), and in later times came to be known as Gallia Narbonensis.

Dangerous tribes

As soon as Caesar reached Gaul he had to face a difficult situation. The Helvetii, a warlike Gallic tribe living in present-day Switzerland, had been under constant pressure from the Germans. They decided to migrate *en masse* through central Gaul and, aided by their allies, to seize the land on the Atlantic coast between the rivers Loire and Garonne, and settle there. This Caesar felt he could not permit – sensibly the Romans always tried to prevent the growth of strong powers just beyond their frontiers.

First the Helvetii asked permission

Gallic silver coin (probably Aeduan)

Julius Caesar's soldiers pursue the Germans

to march westwards through the Province. Caesar refused, and drove back the few who tried to do so. But then the Helvetii persuaded two independent Gallic tribes, the Sequani and the Aedui, to let them march through their territories instead.

A Gallic warrior

Caesar countered by inducing some of the Aedui to appeal for his protection against the Helvetii, most of whom had now crossed the river Arar (Saône). Caesar moved quickly. First he surprised and defeated those Helvetii who had not yet crossed the Arar; then he enticed the remainder to attack him at Bibracte (Mont Beuvray), the Aeduan capital. After a hard-fought battle the Helvetii were defeated and compelled to return to Switzerland.

Caesar now discovered a more serious threat to both Gauls and Romans. In a recent war between the Aedui and the Sequani, the latter had invited help from Ariovistus, a German chieftain. He had settled in Alsace, and was now inviting further hordes of Germans to cross the Rhine and join him. Caesar realised it was pressure from the Germans that had induced the attempted migration of the Helvetii; and he foresaw all kinds of trouble if the Germans were not driven back over the Rhine.

The first step was to defeat Ariovistus. Caesar sent him an ultimatum, which he rejected. Caesar immediately occupied Vesontio (Besançon) as a base, and advanced into Alsace. After some manœuvring, he compelled Ariovistus to fight, probably near Mulhouse. The battle was fierce, but the Roman cavalry reserves turned the scale. The Germans fled in disorder to the Rhine, where most of them were cut down and killed. Ariovistus himself escaped only with difficulty, and died soon afterwards.

Extending Roman domination

The immediate threat was over; but it was clear that German invasions would start again as soon as Caesar withdrew his troops. He realised he would eventually have to extend Roman rule over all Gaul; in particular, if he were to control the Rhine frontier, the Belgae in the north would have to be subdued.

In the spring of 57 B C Caesar advanced north from Vesontio,

to the Rhine; only Ariovistus, with a few companions, managed to escape

and occupied a strong position (probably at Berry-au-Bac) north of the river Axona (Aisne). The Belgic army did not dare to attack, and soon disintegrated. It looked as if Caesar would have no further difficulty in conquering all the Belgae, but late one afternoon his army, while fortifying a camp by the river Sabis (Sambre) was caught unawares by the Nervii and three other fierce tribes. Only fine discipline, and Caesar's personal example of bravery, saved the Romans from annihilation and at last gave them the victory.

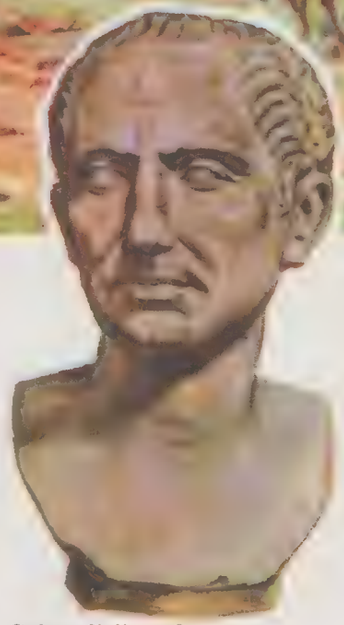
Meanwhile young Crassus (son of Caesar's political ally, see page 870) had secured the allegiance of the Gallic tribes in Normandy and Brittany. All Gaul (except Aquitania) seemed to be under Roman control. But the conquest had been too rapid: it was as if the Gauls had been stunned by Caesar's speed of movement, and by the discipline of the Roman army. Three serious revolts had yet to be put down before Roman control was secure.

The first revolt came from the Veneti in Brittany. Probably Caesar was already planning an invasion of Britain, and the Veneti, a sea-going tribe, controlled trade with Britain, which they feared the Romans would take from them. To quell this revolt Caesar had to build a fleet. (He meanwhile sent young Crassus to conquer Aquitania.) The decisive battle took place in the Bay of Biscay. The Roman sailors disabled the Venetian ships by cutting the ropes of their sails, using sickles fixed to the end of long poles.

Then Caesar had to repel German tribes who had crossed the Rhine again, this time north of Cologne. He treacherously seized their leaders, who had come to parley with him, and massacred the remainder. He then bridged the Rhine, and made a brief demonstration of force on the eastern side.

Silver denarius, commemorating Caesar's victory over Ariovistus

Caesar was now free to invade Britain (his command in Gaul had been extended for a further five years by the agreement of Luca), but it was too late in the year for more than a brief and not very successful reconnaissance (see page 52). His second expedition, in 54 B C, was unpopular with the Gallic chiefs, most of whom he had to take to Britain with him as hostages.



Gaius Julius Caesar, conqueror of Gaul

As soon as Caesar returned to Gaul, the smouldering revolt burst into flames. The Eburones, led by Ambiorix, attacked the Roman garrison at Aduatuca and managed, by treachery, to destroy them. The Nervii besieged Quintus Cicero (brother of the famous orator); but Caesar himself relieved him and defeated them. The Treveri tried in vain to defeat Caesar's officer, Labienus. The revolt did not spread into central Gaul, except among the Carnutes and Senones; these Caesar pacified, before finally defeating the Eburones – though Ambiorix himself escaped. It had now become clear that the Romans considered the Gauls their subjects, not their allies.

The last Gallic stand

The third revolt was the most serious of all, because the Gauls at last produced a really capable leader – Vercingetorix the Arvernian (see page 1760). They seized their opportunity to revolt in 52 B C, when Caesar was away in Italy, and tried to keep him cut off from his legions. Caesar foiled this plan by marching through the Cevennes, a mountain range which the Gauls had thought impassable because of winter snows.

Vercingetorix now embarked on a 'scorched earth' policy, designed to prevent the Romans from obtaining any supplies; but he could not persuade the Bituriges to destroy their capital, Avaricum (Bourges), which Caesar managed to capture, full of provisions. Vercingetorix defeated Caesar's troops at Gergovia (Gergovie), but was compelled to endure a siege at Alesia (Mont Auxois). After some hard fighting Caesar succeeded in defeating the Gallic army which tried to raise the siege. Then at last Vercingetorix surrendered.

The revolt continued spasmodically for a few months, but, bereft of their leader, the Gauls eventually surrendered.

LAMPREYS

ABOUT 40 years ago large numbers of fish were found in the Great Lakes of North America. Every year about 5,000 tons of lake trout and other fish were caught, providing food and employment on a large scale. Then the number caught started to decline disastrously, and soon the Great Lakes' fisheries were of no economic importance. What had happened?

In order to admit shipping to the Lakes, large canals were made connecting them with the sea. This allowed a kind of sea fish, the curious eel-like lamprey (*Petromyzon marinus*), to swim into the Lakes and establish itself there. Lampreys prey on fishes, attaching themselves to their victims' skins and sucking their blood; since the lamprey is 2 or 3 feet long, this quickly kills any moderate-sized fish. No wonder the numbers of fish in the Great Lakes were reduced so drastically and rapidly!

Members of the species that did the damage live in the sea on both sides of the Atlantic, and only go up rivers into fresh water to breed, but those in the American Great Lakes have established a permanent fresh-water population. They now never return to salt water. This is a very unusual thing for a marine animal to do.

Much research has been done on methods of exterminating or reducing the numbers of lampreys in the Lakes. Some success has been achieved, but the problem is still far from being finally solved.

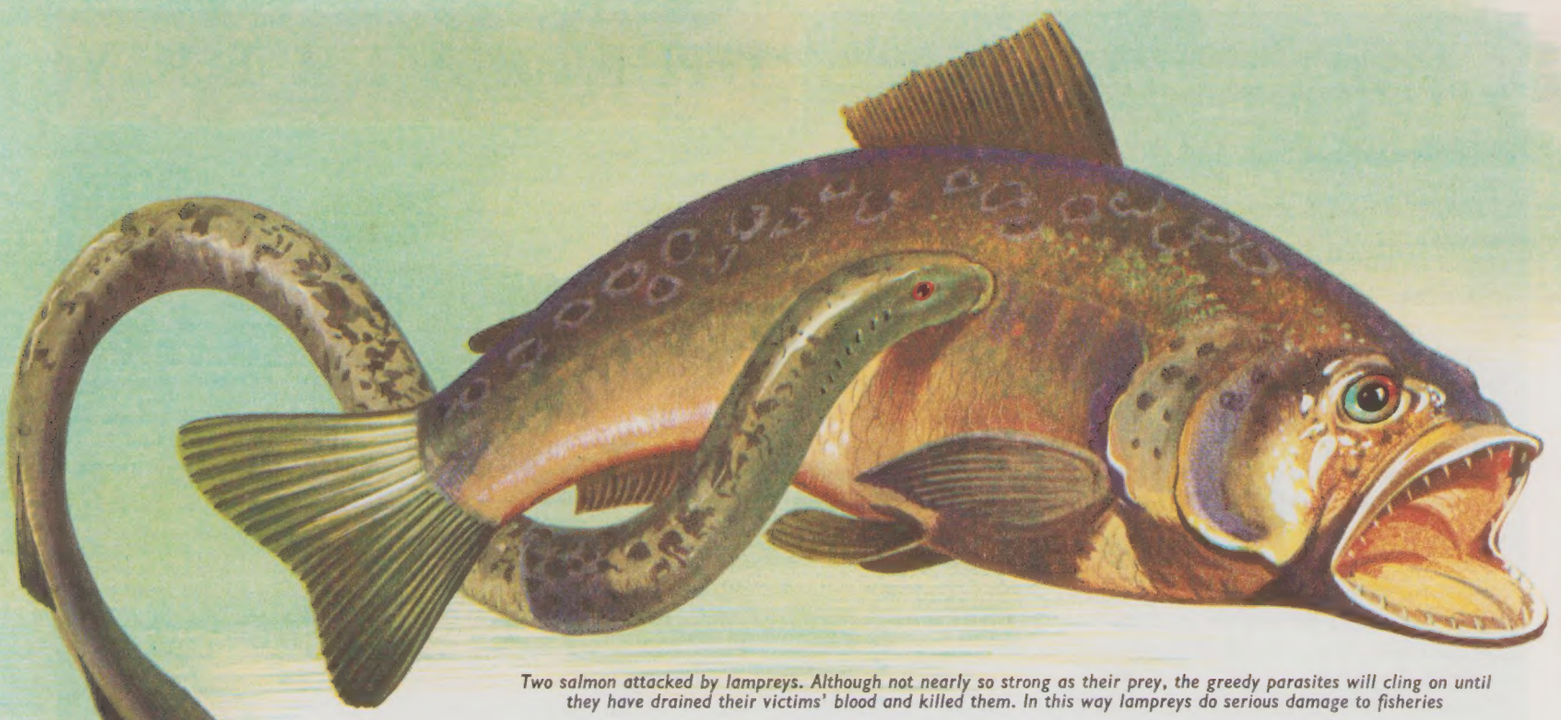
No jaws but formidable teeth

Lampreys belong to the very primitive Class of fishes called the Agnatha, a word meaning 'without jaws'. It is true that the lamprey has no jaws at all, only a round, sucker-like mouth. But inside its mouth are many sharp, horny teeth, curved like thorns, with which the lamprey pierces and clings on to the skin of its prey. Its tongue is also covered with horny teeth. Once it has fastened its sucker-like mouth on to a victim, the lamprey uses its tongue as a file to rasp away the skin and flesh, and then the blood is quickly sucked out. Lampreys feed on almost any kind of fish, and there is no doubt that they destroy great numbers of them, in the sea as well as in the Great Lakes.

Inside a lamprey's mouth; note its thorn-like teeth and muscular tongue

Besides having no jaws, these animals differ from other fishes in having no paired fins and no vertebrae, the place of the backbone being taken by a continuous rod of cartilage, the notochord. They have no scales on their skin, and unlike vertebrate animals of all other Classes they have no sympathetic nervous system. The lamprey has a single nostril on top of its head, and seven openings on each side of its neck, leading to gills which are contained in seven separate pouches, an arrangement entirely different from that found in other fishes.

Three different kinds of lampreys are found in British waters: the sea lamprey (*Petromyzon marinus*), which we have already mentioned; the lampern (*Lampetra fluviatilis*), which has similar habits but differs in the arrangement of its teeth; and the brook lamprey (*Lampetra planeri*), which is smaller and spends its adult life in streams and rivers, not in the sea.



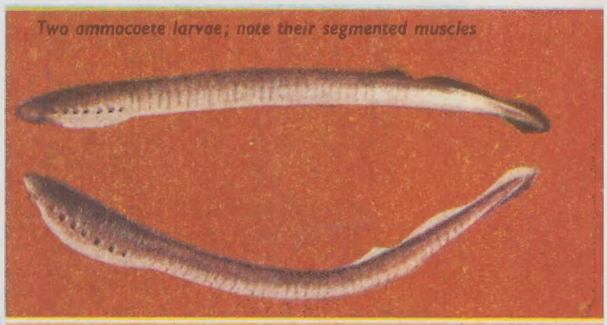
Two salmon attacked by lampreys. Although not nearly so strong as their prey, the greedy parasites will cling on until they have drained their victims' blood and killed them. In this way lampreys do serious damage to fisheries

Breeding

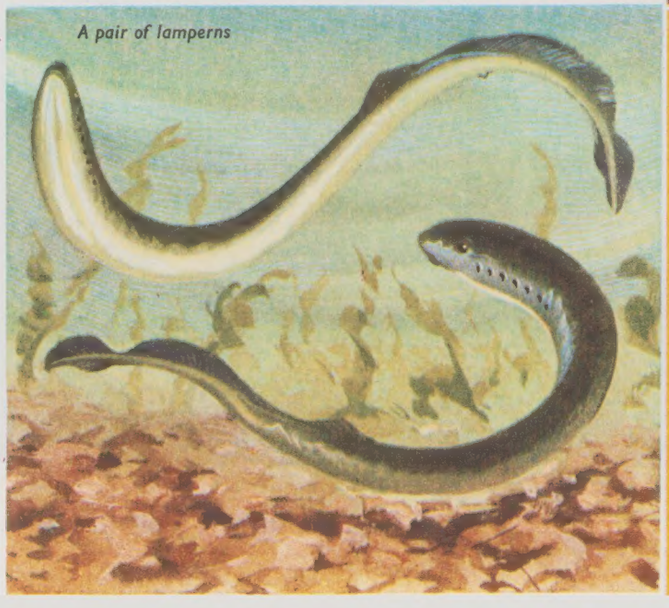
When they are fully grown lampreys swim up into rivers to breed. The male enters the river in February, and looks for a place where the water runs over stones or gravel. He makes a shallow depression in the river bed, moving the stones with his sucker-like mouth. After a time a female joins him. Between them they make a 'nest' of stones, 6 inches deep and a couple of feet in diameter; here the female lays as many as 200,000 eggs. After these are fertilised both the male and female lamprey are exhausted, and soon die.

In about two weeks the eggs hatch into tiny worm-like larvae, which make their way to places where the river is muddy and burrow in the mud there. They have no eyes or teeth, and feed on minute animals and plants which they strain out of the water. For a long time after they were discovered these larvae were thought to be a separate kind of animal, having no connection with lampreys. They were given the name *Ammocoetes branchialis*; and they are still known as ammocoete larvae.

After about four years, when they are 6 inches long, the larvae start to turn into lampreys. Their teeth and sucker-like mouths develop, their eyes appear, and various other changes take place in them. They swim down to the sea where they feed on fishes, and grow to full size in one to two years.



Two ammocoete larvae; note their segmented muscles



A pair of lamperns

CLASSIFICATION

The lampreys and hag-fishes (Subclass Cyclostomata) make up the living members of the Class Agnatha of the Subphylum Vertebrata or backboned animals. The Agnatha is the smallest and most primitive of the Vertebrate Classes. There are only about 45 living species, but fossil Agnatha (many of them armoured and very different from lampreys) have been found in ancient strata. Hag-fishes resemble lampreys, but have blunt tentacles round their mouths and lay large eggs enclosed in horny capsules. They attach themselves to fishes and eat their way into their bodies.

THE BATTERY

EVERYONE has used a battery, perhaps in an electric torch, or as part of some toy driven by an electric motor. Few of us realise, however, that the first forerunner of such batteries is only a little over 160 years old. Details of the invention of the first workable battery were published by the Italian scientist Alessandro Volta in 1800. Since then a lot has been done to make better batteries. But it was through working with Volta's battery that scientists in the early 19th century found out some of the basic facts about electricity, which were to be so valuable for the later advance of science and technology.

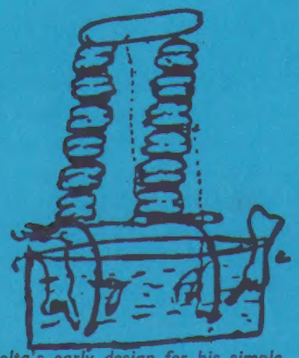
Volta was not the first to experiment with electricity, but before his time the only way of producing it was by rubbing materials like ebonite, sulphur, sealing wax, or amber (the Greek word for amber is *electron*, from which our word electricity is derived). We have probably all tried rubbing one of these materials on a rough cloth, and seen for ourselves how it will attract scraps of paper through the electricity produced. But such pieces of material were not powerful enough to produce a continuous electric current for any length of time. Eighteenth-century scientists became increasingly interested in this subject, but the devices they built had no practical use.

POTENTIAL ENERGY

Before we look at Volta's invention we must realise that electricity passes as a kind of flow or 'current' along bodies that conduct it. We can compare it with similar happenings in other branches of physics. Take two vessels linked by a pipe and filled with water. The liquid flows from the vessel which has the higher water level to that which has the lower. The flow continues until the levels are the same and then stops. To get a flow we must have a difference in level. The water at the higher level has more energy than that at the lower level by virtue of its position; this 'positional' energy is called *potential* energy. The same is true of electricity; there must be a difference of electric level before the current will flow. Such levels are sometimes called *electric potentials*. The flow is from high potential to low potential; the potential difference is measured in volts and is sometimes called the *tension*. In general, whatever causes a flow of electricity is called the *electromotive force*. Thus when there is a potential difference there is also an electromotive force.

EARLY ELECTRIC CELLS

In 1780 Luigi Galvani was studying the nerves of a dead frog which was supported by a brass wire connected to its spinal nerve. He found that if its feet and the brass wire touched an iron disc at the same time, its legs twitched. Galvani realised that when the wire and disc were connected there was a flow of electricity through the frog's nerves. This was perhaps the first electric cell created by man. Volta developed this idea, and made a series of cells, or batteries, from a large number of copper (Cu), zinc (Zn), and moist paper (P) discs arranged as —Zn P Cu Zn P Cu Zn P Cu+. He found that a positive charge appeared on the end copper disc and a negative charge on the zinc disc at the other end.



Volta's early design for his simple battery

To explain Volta's invention let us consider two rods of different metals, such as copper and zinc. If they are immersed in a liquid conductor, such as a solution of dilute sulphuric acid, enough energy is produced to keep up the potential difference between the two metals for a little while. A useful current can thus be obtained. The potential between the two rods is about 1 volt (this unit of measurement, set up at a later date, was called after the inventor of the battery). The dilute sulphuric acid attacks the zinc but not the copper, and this chemical reaction sets free negative electric charges (or *electrons*) on the zinc rod. If we now join the two rods by a wire outside the solution, the store of electrons that has accumulated in the zinc rod will flow through the wire to the copper rod. More zinc atoms dissolve into the solution, more electrons are set free; and the current will continue to flow. This is maintained so long as the chemical reaction goes on. The electric current results directly from the energy set free by the chemical reaction in the battery. The amount of electric current depends on how much matter enters into reaction in the battery (formed of a number of 'cells' like the apparatus we have described).

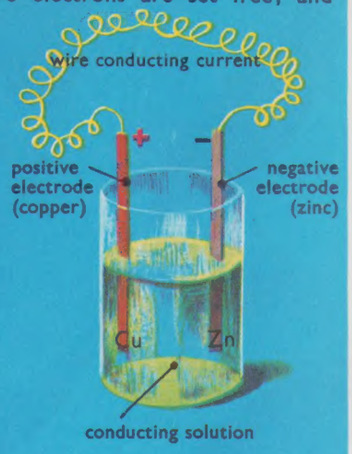
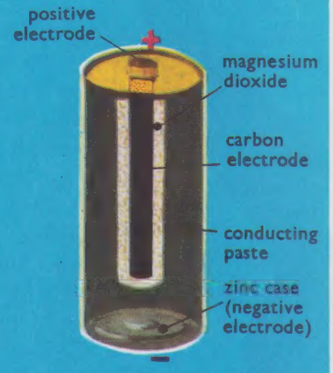


Diagram of Volta's cell

DRY CELL OR POCKET BATTERY

Volta's battery was ingenious, but for practical use it was too cumbersome. For many purposes we now use a dry cell or pocket battery. Here the rods, or electrodes (from the Greek *odos*, path; 'the path of electricity'), are embedded in a paste. The positive electrode is a carbon rod in a manganese dioxide sheath. The negative electrode is the amalgamated zinc container filled with a mixture of ammonium chloride and gelatine. This kind of battery produces a potential of about 1·5 volts.

The cells of a battery can be joined together in series, with the positive electrode of one cell connected to the negative electrode of the next. The voltage between the negative electrode of the first cell and the positive electrode of the last cell will be equal to 1·5 × the number of cells. Alternatively, the negative electrodes can be joined together and the positive electrodes joined together. The voltage will still be 1·5 volts, but a larger current can be taken from the battery. In this case the cells are said to be connected in parallel.



Cut-away diagram of a dry battery

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The Fibonacci sequence. This is one of the more fascinating aspects of mathematics, called after the 13th-century Italian mathematician. If you take the sequence of numbers 1 1 2 3 5 8 13 21 34 and so on you will find that each number is the sum of the two immediately before it – for example, 13 = 8 + 5.

The numbers in this sequence crop up over and over again in nature. For example, take the drone (male) bee. It has a mother but no father, for all the *fertilised* eggs laid by the female bee hatch into females. If you work out the number of ancestors which the drone has in each generation, bearing in mind that each female bee has two parents and each drone one, you will find the sequence of numbers in the Fibonacci sequence. The numbers of petals of most flowers are those in the sequence; for example, the lilies have three, the common buttercup five, the flower head of ragwort 13, the field daisy 34, and Michaelmas daisies 55 and 89.

Mathematics in everyday life

Computer mathematics. Computers are now solving problems as varied as wages in large organisations, the signals sent by experimental earth satellites, the orders of large chains of shops, the analysis of results of large surveys, and so on. They count with electric currents (as opposed to fingers). The current is either flowing in one direction or the other, the directions being represented by 0 and 1. So the computer has only two alternatives for symbols for numbers – 0 and 1. We, on the other hand, use 10 symbols (0 to 9) – our system is called the decimal system because its base is 10 (0 to 9 and the separate use of each of these figures to express multiples of 10). Because the computer system is based on two symbols it is called the binary system, from the Latin *binarius*, meaning 'of two'. In this system 1 + 1 cannot be written as 2, so it is written 10. 1 + 1 + 1 = 10 + 1 = 11, and so on.

This may seem slightly cumbersome, but the great advantage of the computer is that its electric currents can be switched in an incredibly short time – 10^{-6} seconds or even faster. The work that needs months to be done by hand can be done in minutes. But even computers can have their 'human' side; one has been set to print out the word NUTS if told to do something foolish, like divide 1 by 0.

Statistics is a branch of mathematics dealing with the collection and arrangement of facts, dates, and opinions, relating to human affairs or natural phenomena, and drawing conclusions from this data. Today statistics are very widely used in such things as Gallup polls, market and audience research, and planning of rail and bus services.

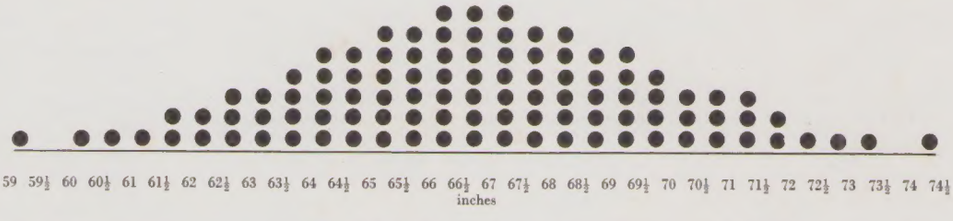
For example, before a general election many people are anxious to know which political party will gain a majority. To find this out in advance, you could ask the whole population of the British Isles which way they would vote. This would be extremely laborious and costly. An efficient and easy way is to take a representative sample (people of every age and every class group affected by the election), and ask the chosen people what they think. The result of the findings would be expressed in the form of statistics. 40 per cent of the people might vote Conservative; 40 per cent Labour; and 20 per cent Liberal. One would induce from this that the chances of the Liberals winning the election were not very great and that the chances were balanced evenly between the Conservative and Labour parties. If the sample is big enough, and is chosen correctly, your conclusions could well be right. The more people asked, the greater the probability of the results being a good guide. This is another example of induction.

Suppose you were a manufacturer of men's suits and wished to know how many of each size to make. You would need to know the average height of men, and the variation about that average. Take 100 men at random and measure their height. This would give you a graph like the one below, which represents a situation like that shown in the illustration. This is called a normal distribution. It shows that the mean (average) height is 67 inches (5 feet 7 inches); that two-thirds of men are between 5 feet 4 inches and 5 feet 10 inches: and that 96 out of 100 are within 6 inches of the mean.

The sample of men must be random, or strange results would occur – if you took 100 men who worked at racing stables, their average height would be unusually low as so many would be jockeys.

A random group of men. The majority are of a middling height

These illustrations were taken from *The Language of Mathematics* by F. Land (published by John Murray)



Each dot represents a man. The table shows that most of the group of 100 *men are of middling height*

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MATHEMATICAL A B C

Abacus: The earliest type of calculating machine. It used rows of pebbles or beads.

Algebra: The branch of mathematics which investigates the relationship between numbers by means of general symbols – the shorthand of mathematics.

Angle: The degree of rotation of one line with respect to another. The degree of inclination of two lines to each other.

An abacus in use

Antilogarithm: The converse of a logarithm; for example, $log 10^2 = 2$, and $antilog\ 2 = 10^2 = 100$.

Arithmetic: The science of numbers.

Calculus: A method of calculation of use when one or more quantities are varying; for example, changing velocity.

Cardinal numbers: 1, 2, 3, and so on. See *ordinal numbers*.

Circle: A plane figure bounded by a closed single line, called the circumference, which is everywhere equidistant from a point within it called the centre.

Cone: A solid generated when a straight line, which always passes through a fixed point called the vertex, is rotated about another line through that point. Any point on the rotated line describes a circle.

Cosine: The cosine of an angle in a right-angled triangle is the length of the side adjacent to the angle, divided by the length of the hypotenuse (the side lying opposite the right angle).

Cube of a number: The number multiplied by itself twice.

Decimal system: System of numbers based on the unit 10.

Differentiation: An operation in calculus that yields the slope of the tangent to a curve at any point on the curve.

Dynamics: The part of mathematics dealing with moving bodies.

Ellipse: A close curve (not a circle) formed when a plane intersects a cone.

Equation: A mathematical statement that two quantities or expressions are identical in value.

Factors: The factors of a number or expression are two or more numbers or expressions which, when multiplied together, produce the original.

Fraction: One or more parts of a unit or whole number. The statement of a number or expression as one number or expression divided by another.

Geometry: The part of mathematics which investigates the properties of and relations between magnitudes of lines, surfaces, and solids.

Graph: The representation of a mathematical equation as a curve, making it easier to see the relation between the quantities.

Hyperbola: The figure formed when a plane intersects a cone such that the angle of the plane with the base is greater than that between the sides of the cone with the base.

Integration: An operation in calculus that can give the area under a curve on a graph.

Logarithm: The expression of one number as the power of another; for example, logarithm of 100 to the base 10 is 2 ($10^2 = 100$).

Mechanics: Department of applied mathematics which deals with forces in motion and tendencies to motion.

Ordinal numbers: 1st, 2nd, 3rd, and so on.

Parabola: The figure formed by the intersection of a cone with a plane parallel to a line on the surface of a cone.

Parallel lines: Straight lines in the same plane, which never meet, however far produced in any direction.

Permutation: Changing the order of a set of things linearly arranged.

π (pi): The length of the circumference of a circle divided by the length of the diameter (pronounced 'pie').

Polygon: A many-sided plane figure.

Prime number: A whole number which is divisible by no other number except 1 and 0 and itself, without leaving a fraction.

Quadrilateral: Any four-sided plane figure.

Ratio: The relation between two quantities determined by the number of times one contains the other.

Rectangle: A quadrilateral with four right angles.

Rhombus: A quadrilateral with four sides equal.

Series: A set of numbers or expressions in succession (finite or infinite in number), the value of each of which is determined by its position in the series according to a definite rule or law of the series.

Significant figures: The number of figures to which a number is given; sequences of 0s at the end of a whole number or at the beginning of a decimal fraction are not counted. For example:
the value of π to 2 significant figures is 3·1
π to 6 significant figures is 3·14159

Sine: The sine of an angle in a right-angled triangle is the length of the side opposite the angle divided by the length of the hypotenuse.

Square: A quadrilateral with four equal sides and four right angles.

Squared number: A number multiplied by itself once.

Statics: The part of applied mathematics which deals with stationary bodies.

Tangent: The tangent of an angle in a right-angled triangle is the length of the side opposite the angle divided by the length of the side adjacent to the angle.

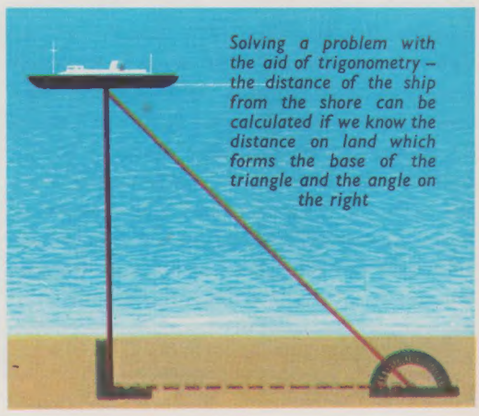
Tangent to a curve: The tangent at a point on a curve is the line which touches the curve at that point.

Trapezium: A quadrilateral with two unequal sides parallel.

Triangle: A plane figure with three angles and three sides.

Trigonometry: This deals with the measurement of angles and sides of triangles and other plane figures.

Zero: Nought; the intermediate between positive and negative numbers.



Solving a problem with the aid of trigonometry – the distance of the ship from the shore can be calculated if we know the distance on land which forms the base of the triangle and the angle on the right